ALGORITHM DEVELOPMENT FOR BREAK-EVEN ANALYSIS OF UNMANNED AERIAL VEHICLE

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Abstract

Break-Even Analysis is an important step to be considered in the design process of a product. In order to facilitate this cost analysis in the framework of unmanned aerial vehicle design, a numerical algorithm is proposed and implemented on an in-house software. The developed algorithm adopts the cost components of Modified DAPCA IV Cost Model. It aims to calculate the number of units to achieve Break-Even Point and its corresponding unit price, as well as the obtained profit margin. Three example cases are employed in the assessment of the proposed algorithm for solving two types of calculation. Case 1 and Case 2 are based on Type 1 calculation (i.e. for obtaining the number of UAV produced to achieve BEP at a certain unit price). Meanwhile, Type 2 calculation, for calculating the unit price of UAV to achieve BEP at a desired number of unit produced, is performed in Case 3. All example cases produce reasonable results, and good agreements with theoretical trends are concluded.

Keywords: break-even analysis, break-even point, unmanned aerial vehicle, profit margin

Abstrak

Analisis titik impas merupakan sebuah langkah penting yang perlu diperhitungkan pada proses desain suatu produk. Untuk memfasilitasi analisis biaya tersebut pada desain pesawat tanpa awak (PTA), suatu algoritma numerik diusulkan dan diimplementasikan pada suatu perangkat lunak yang dikembangkan sendiri. Algoritma yang dikembangkan mengadopsi komponen biaya pada Modified DAPCA IV Cost Model. Algoritma tersebut bertujuan untuk menghitung jumlah unit untuk dapat mencapai titik impas dan harga yang berkesesuaian dengannya, serta margin keuntungan yang diperoleh. Tiga buah contoh kasus digunakan dalam penilaian algoritma yang diusulkan untuk menyelesaikan dua tipe perhitungan. Kasus 1 dan Kasus 2 berdasar pada perhitungan Tipe 1 (untuk memperoleh jumlah PTA yang diproduksi dan dijual untuk mencapai titik impas pada harga tertentu). Sementara itu, perhitungan Tipe 2, untuk menghitung harga unit PTA untuk mencapai titik impas pada jumlah unit tertentu yang diinginkan, dilakukan pada Kasus 3. Keseluruhan contoh kasus menghasilkan hasil yang dapat dipercaya, dan sesuai dengan tren secara teoritis.

Kata kunci: analisis titik impas, titik impas, pesawat tanpa awak, margin keuntungan

1. Background

Design and production processes of Unmanned Aerial Vehicle (UAV) have become great interest in Indonesia for about the last decade. The processes are mainly done in small to middle scale industry (e.g. home industry) with relatively small number of labor worker. In order to ensure the sustainability of the industry or company, Break-Even Analysis (BEA) is one of the most important steps to be conducted before finalizing the design and going to production stage.

In cost analysis of UAV, a market study accompanied by BEA is a major determinant on the prediction or investigation of potential risks. BEA provides information that correlate between costs and revenue, and determines the requirements to obtain positive sales return (i.e. profit) in terms of number of unit produced and the corresponding unit price, or vice versa. Rigorous mathematical treatment for BEA can be found in the study of Kampf et al. [1]. BEA have been widely performed in many applications for business and industry. For instance, Break-Even Point (BEP) was investigated for decision making in mining industry [2]. BEA had also been discussed and utilized, albeit not in exactly the same business characteristics with UAV, for the calculation of BEP in several daily business activities [3]. In the study, examples of analyses were performed for pen production and selling company, cafeteria, bus rental, and cinema. BEA was also employed for sake of monthly financial administration for small retailers [4]. Due to the importance of this analysis, some researchers included more complex methods and analyses to improve and develop BEA. An extension analysis of BEA implementing fuzzy estimators was also found [5].

In this paper, a numerical algorithm is developed to facilitate break-even analysis of UAV. The developed algorithm is implemented on an in-house software code written in Python language. Cost-revenue relationships become the main results of the program with additional discussion of profit margin obtained after reaching Break-Even Point (BEP). Three example cases are given to investigate the outcomes of the developed algorithm.

2. Method

In this paper, numerical algorithm of BEA is proposed for cost analysis of UAV in the scale of small or home industry. The analysis considers costs and revenues components based on small number of produced units (i.e. not in mass production). Several more complex financial terms (e.g. interests, inflation, tax, insurance, dynamic pricing) are still omitted, and may be included in the extension analysis. The costs and revenues considered in this analysis are categorized based on the method of Modified DAPCA IV Cost Model [6] with extended modification for the implementation in UAV.

2.1 Costs

Two types of costs are considered, namely fixed and variable costs. The fixed cost is considered as constant and independent to the number of unit produced. This is mainly related to the costs at development stage, and consequently has non-zero value when the produced unit is still zero. It is noteworthy that the term 'unit produced' refers to the unit sales. This means that the number of UAV built in the development stage is not counted. Meanwhile, variable cost is a function of the number of unit produced. Due to the simplification regarded in this analysis, the variable cost will grow in linear manner when the number of unit produced increases.

According to the Modified DAPCA IV Cost Model, several costs components in the aircraft design and fabrication stages are considered as follows: engineering, tooling, manufacturing, quality control, development support, flight test, material, engine, and avionics. It is assumed here that the produced UAV has a very limited avionics system, thus the avionic cost is omitted. Any cost related to avionics, if any, may be included in another component, for instance: the system related to engine can be included in engine cost component. The fixed cost is then obtained by calculating the following components:

- Engineering cost (F_{EG})
- Tooling cost (F_{TO})

- Manufacturing cost (F_{MN})
- Quality control cost (F_{QC})
- Development support cost (F_{DS})
- Flight test cost (F_{FT})
- Material cost (F_{MT})
- Engine cost (F_{EN})

Total fixed cost (FC) are given by the following equation

$$FC = F_{EG} + F_{TO} + F_{MN} + F_{QC} + F_{DS} + F_{FT} + F_{MT} + F_{EN} \quad (1)$$

By considering that development support and flight test are not taken into account in the production stage, the costs of both components are not included in the calculation of variable costs. The total variable cost per unit produced (VC) are then obtained as follows

$$VC = V_{EG} + V_{TO} + V_{MN} + V_{QC} + V_{MT} + V_{EN} \quad (2)$$

where V_{EG}, V_{TO}, V_{MN}, V_{QC}, V_{MT}, and V_{EN} are variable cost components for engineering, tooling, manufacturing, quality control, material and engine, respectively. The variable cost is actually a linear function of the number of unit produced. This can be mathematically expressed by the following equation

$$VC(x) = (V_{EG} + V_{TO} + V_{MN} + V_{QC} + V_{MT} + V_{EN})x \quad (3)$$

where x is the number of unit produced. The total cost (TC), i.e. combination of total fixed and variable costs, consequently becomes a function of number of unit produced and can be written as follows

$$TC(x) = FC + VC(x) \quad (4)$$

2.2 Revenues

In this analysis, revenue is simply obtained through the consideration of unit sales (number of UAV sold) and unit price. The unit price is assumed to be constant along the sales process. Such kind of assumptions yield the following equation

$$R(x) = Px \quad (5)$$

In Eq. (5), $R(x)$ means that the revenue (R) is a function of the number of unit sales (x), while P denotes the unit price.

2.3 Algorithm of Break-Even Analysis

The most important part in break-even analysis is calculation of break-even point (BEP). BEP can be regarded as a point when total cost and revenue are balance, or start to obtain a positive return. This can be achieved when the following relation agrees

$$R(x) \geq TC(x) \quad (6)$$

It is important to note that x in the context of Eq. (6) belongs to both number of unit produced as well as number of unit sales, and indeed the same value. The variable x can now be generalized as quantity. For better understanding, schematic representation of typical BEA is given in Fig. 1.

When BEP is already reached, positive return (i.e. profit) can be calculated. In this analysis, a profit margin curve is also included. The profit margin (M), as a function of x, is calculated by the following equation

$$M(x) = 100\left[\frac{R(x) - TC(x)}{R(x)}\right] \quad (7)$$

An algorithm to facilitate BEA as well as calculate profit margin is developed. The algorithm is briefly represented through the following flowcharts given in Figs. 2-4. In Fig. 2, Step (2) includes several input processes for storing necessary input values. The processes are conducted by reading an input file. In the file, user is required to define several values including all fixed and variable costs components. User is also mandated to choose the type of calculation between two types of choices. Type 1 means that the user wants to obtain the number of UAV produced to achieve BEP at a certain unit price, and the desired unit price has to be filled in the input file. Meanwhile, Type 2 will order the software to calculate the unit price of UAV to achieve BEP with a certain number of unit produced as the input. Once the input values have been readily stored, Step (3) is then executed to calculate FC and VC based on Eqs. (1) and (2).

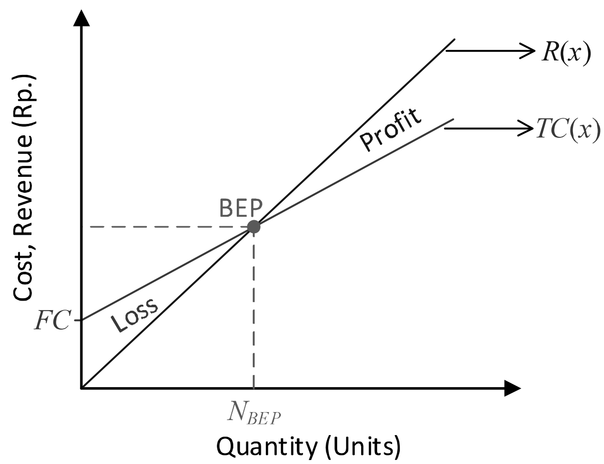


Figure 1 Typical Break-Even Analysis (modified from Ref. [1]).

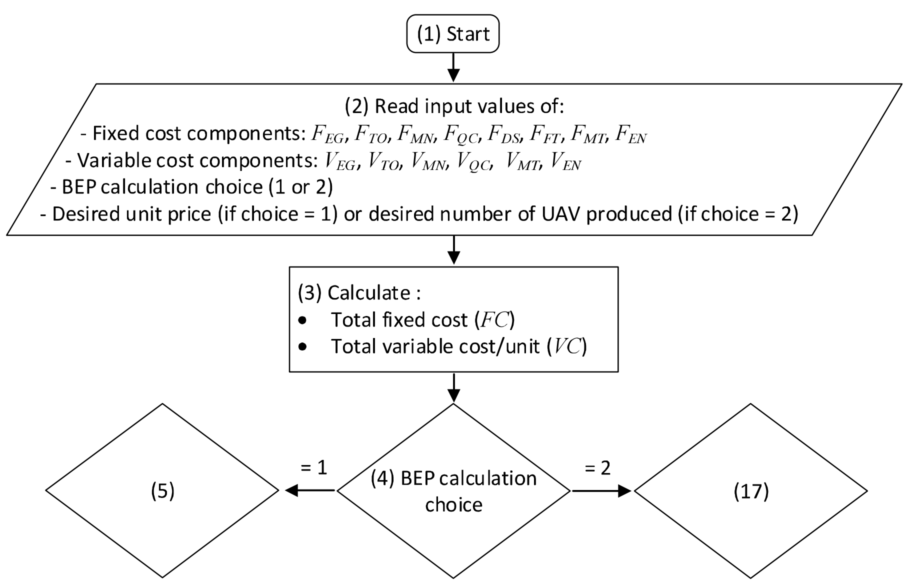


Figure 2 BEA Algorithm (Part 1).

When the user orders the calculation Type 1, Steps (5) – (16) in Fig. 3 are executed. Step (5) will firstly check whether the unit price input is a correct number. In the case of wrong input value, a notification will be given (Step (6)). If the input is correctly a number, Step (7) will check whether BEP can be achieved. It is noted that BEP will never be reached if the unit price P is less than or equal to the total variable cost per unit produced VC. In such case, a notification will be displayed (Step (8)). If Step (7) determines that BEP is obtainable, calculations of total cost $TC(x)$ and revenue $R(x)$ are conducted for unit produced $x = 1$ in Step (9) by using Eqs. (4) and (5). Step (10) will then compare between $R(x)$ and $TC(x)$. If $R(x) < TC(x)$, calculation of $R(x)$ and $TC(x)$ will be passed to Step (11) for $x = x + 1$. Once the looping condition in Steps (10) and (11) is not satisfied, the last counted x becomes the obtained N_{BEP} (Step (12)) and is included in the remarks for user notification (Step (13)). Step (14) is then performed to arrange arrays for $TC(x)$, $R(x)$, and $M(x)$ through the use of Eqs. (4), (5) and (7) for $x = 0$ to $2N_{BEP}$, and the results will be plotted (Step (15)).

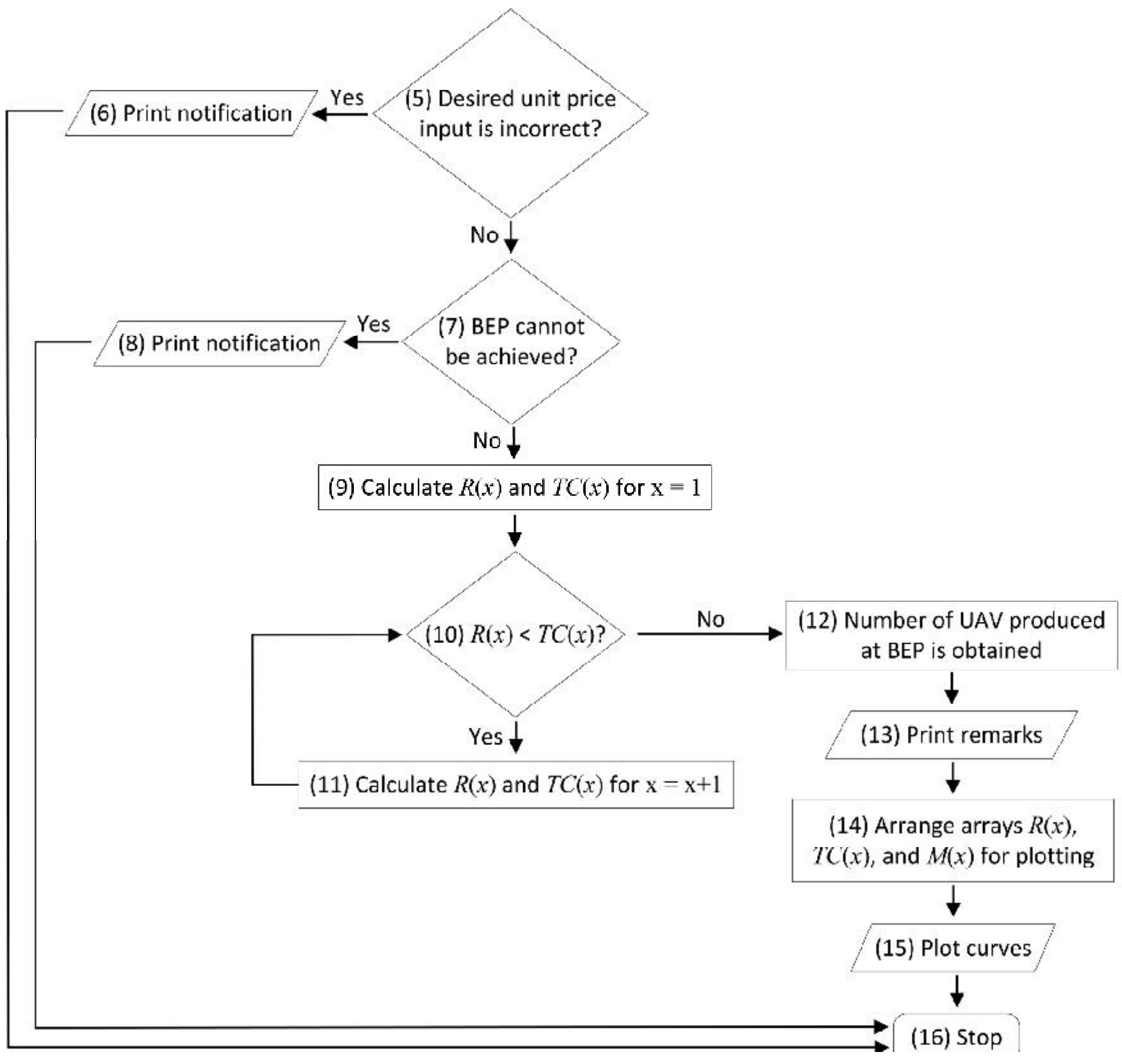


Figure 3 BEA Algorithm (Part 2).

If the choice of calculation is Type 2, the steps in Fig. 4 are executed. Similar to the Type 1, Step (17) will firstly check whether the input is a correct number. A notification will be displayed in the case of wrong input value (Step (18)). Step (19) will be executed only if the input is correctly a number, and the unit price at BEP for a certain number of produced unit (P_{BEP}) can be calculated by the following equation

$$P_{BEP} = \frac{N_{BEP}(VC) + FC}{N_{BEP}} \tag{8}$$

Once the unit price P_{BEP} is obtained, Steps (20) – (22) will be performed in similar manner with those of Type 1 in Steps (13) – (15).

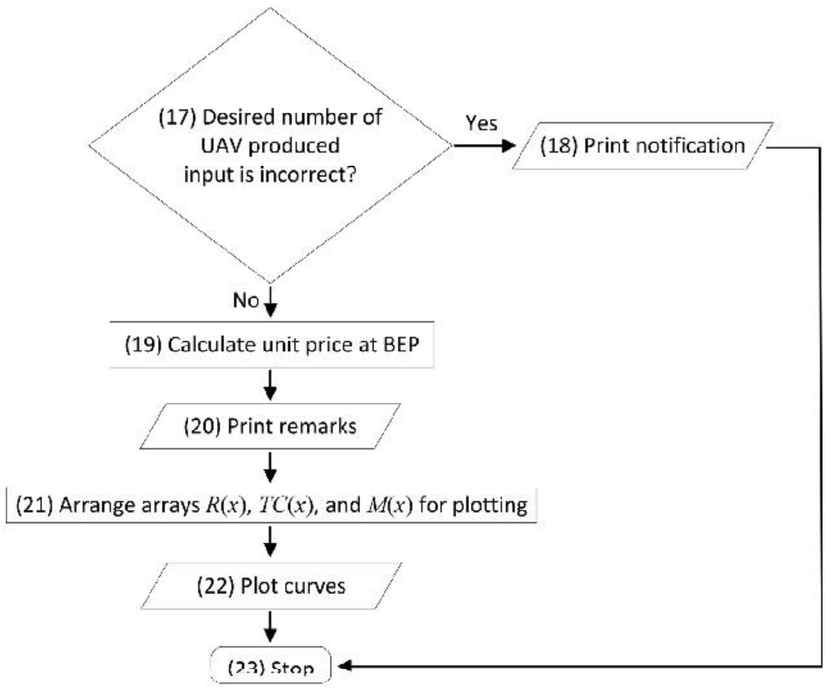


Figure 4 BEA Algorithm (Part 3).

3. Results and Discussions

An assessment to the developed algorithm is conducted by using three example cases. All cases utilize fixed and variable cost components values which are listed in Table 1. The values are assumed based on author's experience. In Case 1, the Type 1 (i.e. to calculate number of UAV produced to achieve BEP at a certain unit price) is chosen with a desired unit price input of Rp. 10,000,000.00. Fig. 5 shows the input file of this case.

Table 1 Values of Costs Components for Example Cases

No.	Cost Components	Fixed Costs (Rp.)	Variable Costs (Rp.)
1	Engineering	59,787,000.00	19,929,000.00
2	Tooling	5,595,000.00	1,865,000.00
3	Manufacturing	1,500,000.00	500,000.00
4	Quality Control	1,000,000.00	100,000.00
5	Material	10,020,000.00	3,340,000.00
6	Engine	10,495,000.00	3,495,000.00
7	Development Support	9,267,000.00	-
8	Flight Test	1,000,000.00	-

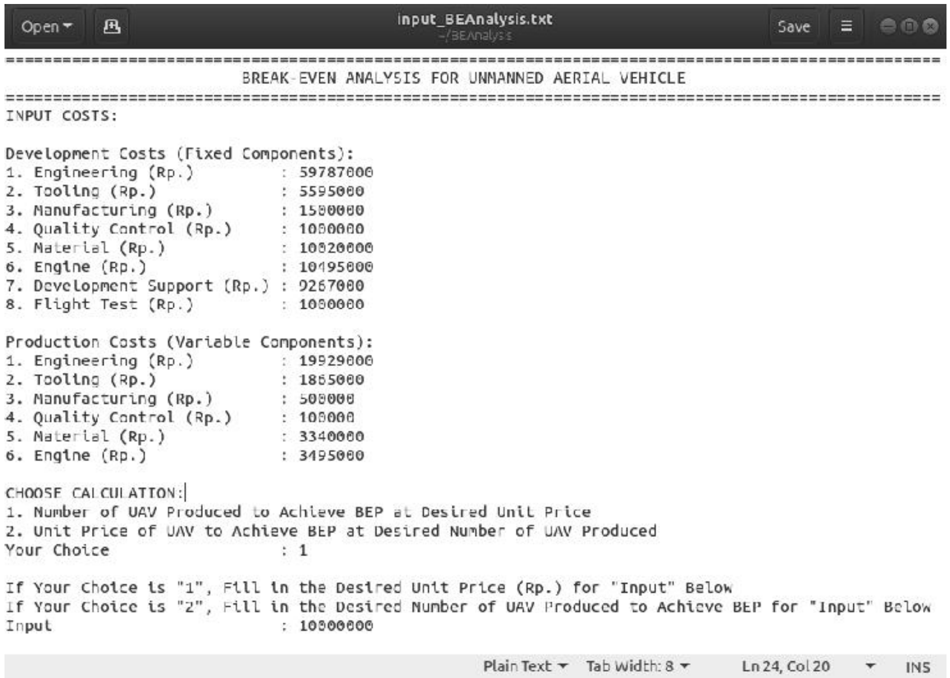


Figure 5 Example of Input File (Case 1).

Due to the condition that the desired unit price (Rp. 10,000,000.00) is less than the total variable cost per unit produced (Rp. 29,229,000.00), the selection process in Step (7) will results in 'yes' and Step (8) is executed. A notification will be included in the remarks to indicate the user. The remarks of Case 1 are shown in Fig. 6.

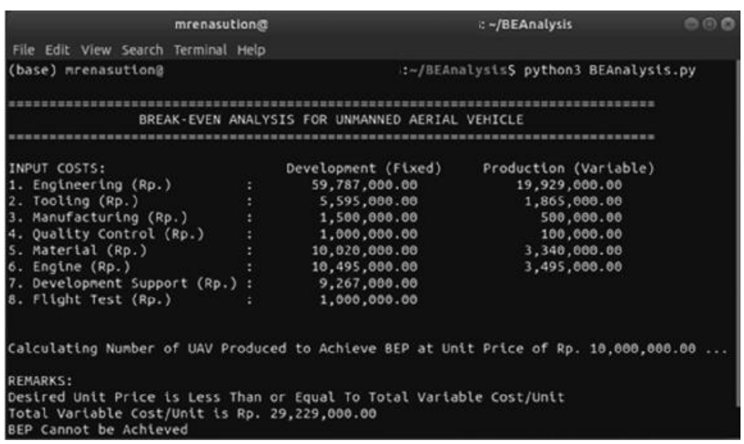


Figure 6 Output of Case 1.

In Case 2, the Type 1 is again chosen with a unit price of Rp. 35,000,000.00 as an input. In order to satisfy this condition, the input file shown in Fig. 5 is slightly modified by replacing the blank of 'Input' with 35000000.

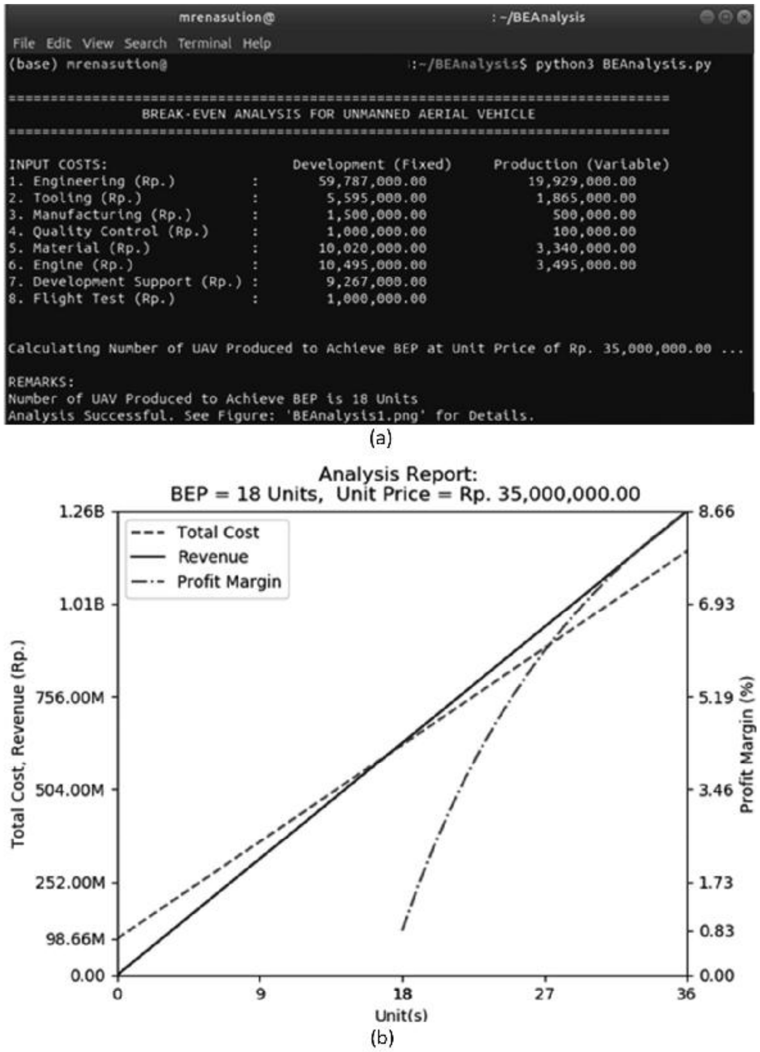
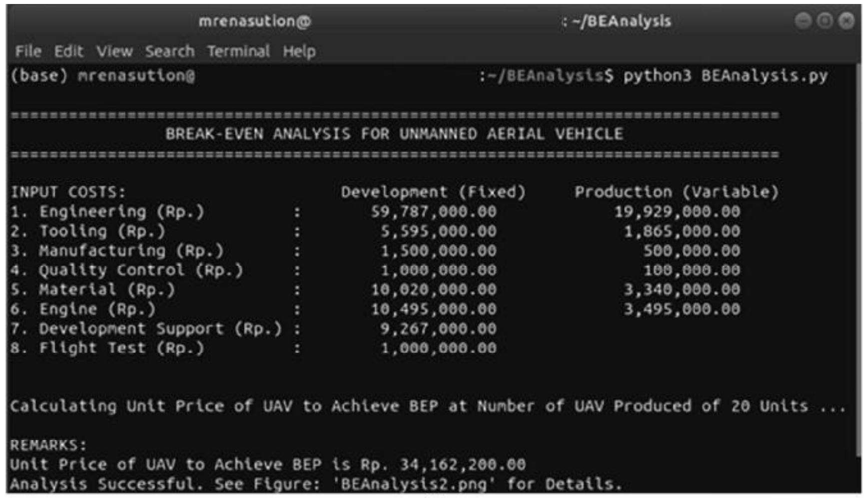


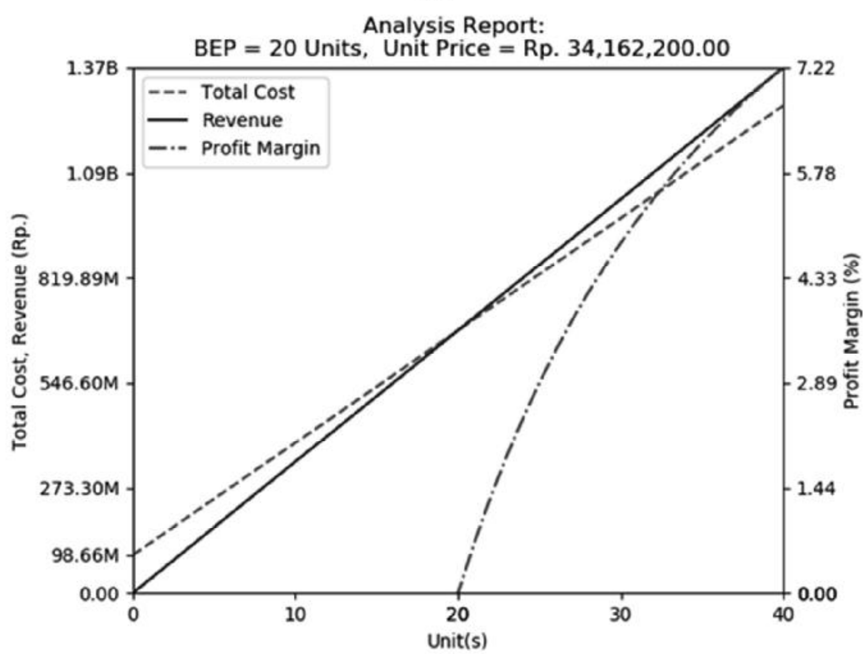
Figure 7 Output of Case 2: (a) Remarks, (b) Figure.

Fig. 7 shows the results of Case 2. Due to the fact that the given input of unit price is more than the total variable cost per unit produced, Steps (9) – (15) are executed. Several important remarks of the calculation are shown in Fig. 7(a), while the details are given in Fig. 7(b). The obtained results elucidate reasonable outcomes and trends. It is concluded that the desired unit price will be able to achieve BEP at the number of unit sales of 18 units. Profit is then calculated afterwards, in which profit margin of 8.66% are obtained when the sale reaches $2N_{BEP}$ (i.e. 36 units). It is important to note that the plotting limit of $2N_{BEP}$ can easily be changed by a simple modification within the algorithm code.

For Case 3, the chosen calculation is Type 2 (i.e. to calculate unit price of UAV to achieve BEP at a certain number of UAV produced). The calculation employs an input of number of UAV produced of 20 units. This case will be satisfied by modifying the input file in Fig. 5. The blanks of 'Your Choice' and 'Input' are now filled with 2 and 20, respectively.



(a)



(b)

Figure 8 Output of Case 3: (a) Remarks, (b) Figure.

In Fig. 8, the output results of Case 3 are presented. Similar to those of Case 2, the obtained outcomes are also deemed reasonable. From this case, the unit price of Rp. 34,162,200.00 is claimed in order to reach BEP at the desired number of unit sales. It is also shown in Fig. 8(b) that a profit margin of 7.22% are obtained at the number of UAV sales of 40 units. Based on the results of the three cases, the two scenarios of calculation (Type 1 and Type 2) are successfully performed by the developed algorithm.

4. Conclusions

A numerical algorithm had been developed for break-even analysis of UAV, and implemented on an in-house software. The developed BEA categorizes cost and revenue components based on the Modified DAPCA IV Cost Model with some modification for adapting the application of UAV. The algorithm facilitates several important numerical quantities in BEA such as number of unit to achieve BEP and its corresponding unit price, as well as the obtained profit margin. Three example cases are utilized for sake of assessment to the output results of the implemented algorithm. The calculations of the number of UAV produced and its corresponding unit price in Case 2 and Case 3 result in reasonable values. In the case that the desired unit price yields unachievable BEP (Case 1), a notification will be reported in the remarks. Good agreements are elucidated between the outcome trends of the developed software and typical theoretical results.

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